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Hao Feng
Ming Lu

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Institute of Economic Research
Hitotsubashi University
2-1 Naka, Kunitatchi Tokyo, 186-8601 Japan
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Abstract: The extent to which the quantity and quality of education is capitalized into housing prices is a key issue in understanding the relationship between allocation of educational resources and the housing market. Using monthly panel data of 52 residential areas in Shanghai and employing a natural experiment of designating Shanghai Experimental Model Senior High Schools (EMSHS), we find that housing prices in Shanghai have capitalized the access to quality schools and other public goods. One quality school per square kilometer raises average housing prices by approximately 19%, and one best EMSHS per square kilometer increases housing prices by 21%. We also match the schools designated for EMSHS with schools of similar quality but not designated for EMSHS, and compare housing prices in the corresponding areas. We find that the designation increased the housing prices, showing that dissemination of information about school quality was significantly affected by the designation.

Keywords: Education, Housing market, Capitalization, Public goods, Natural experiment.

* Hao Feng, School of Economics, Fudan University, E-mail: fenghao1011@sina.com. Ming Lu (correspondence author), School of Economics, Fudan University and Zhejiang University; Tel: (021) 55665308; E-mail: lm@fudan.edu.cn. The research is funded by the National Social Science Funds, Peking University-Lincoln Institute of Land Policy, and the Shanghai Leading Academic Discipline Project (B101). This research is also supported by the Fudan Workshop of China Economic and Social Studies. The authors are grateful to conference and seminar participants at Fudan University, Shanghai University of Economics and Finance, Southwestern University of Economics and Finance, Peking University, and China's Young Economist Society for their comments. The authors also thank for financial support for English proofreading by the Research Project of Policies for East Asia and the G-COE Hi-Stat, Hitotsubashi University. The content of this article is the sole responsibility of the authors.

1. Introduction

The extent to which the access to quality education is capitalized into housing prices is a cornerstone in modern economic theory of educational resource allocation. However, when the correlation between educational quality and housing prices is observed, the causal effect may be from housing to education because only the rich can afford expensive housing, and they, having strong preferences for human capital investment, are willing to pay for high-quality education. Therefore, generally the capitalization of education is upwardly biased in an estimation of the relationship between educational quality and housing prices. Education reform and development of housing markets in China provide a natural experiment that traces the causality from education to housing prices. In the Shanghai case, 50 quality schools were designated as Shanghai Experimental Model Senior High Schools (EMSHS) during education reform in 2005 and 2007. Since there was no official disclosure of schools' quality rankings in the past, information regarding school quality is imperfect in Shanghai. The designation of schools for EMSHS, which occurred in several waves, revealed the information about the school quality, and this disclosure might influence housing prices. Since disclosure of this information about school quality was exogenous to housing prices before and after the designation, this study employs a natural experiment to examine whether the educational quality is reflected in housing prices. Also, whether the designation had significant effects on housing prices can provide evidence for imperfect information in education market, because had information been perfect, the designation would not have significant effects on school choice.

There have been many studies on how educational quality might be capitalized in housing prices. Tiebout (1956) theoretically analyzed how the provision of public goods may be capitalized through "voting with feet" and intergovernmental competition. Oates (1969) empirically studied the correlation between housing prices and the level of local public expenditures and taxation. But the endogeneity of educational quality and quantity is always an obstacle in empirical studies identifying the causal effect from education to housing

prices. A common method of overcoming this problem is using the boundary discontinuity design (BDD) that compares neighboring administrative districts with different education resources (Black, 1999; Gibbons and Machin, 2003; Bayer and McMillan, 2005; Kane, Staiger, and Reigg, 2005; Gibbons, Machin, and Silva, 2009). Our estimation strategy involves a natural experiment occasioned during reform of education and development of housing markets in China. Along with an estimation of the relationship between educational quality and housing prices by using the full sample of monthly panel data of 52 residential areas in Shanghai, we estimate the effect of EMSHS designation on housing prices in order to alleviate the endogeneity bias. We find that housing prices in Shanghai have capitalized the quality and quantity of education and other public goods. One quality school per square kilometer raises housing prices by about 19%, and one best EMESHS per square kilometer increases housing prices by 21%. We compare schools designated for EMSHS with schools of similar quality but not designated for EMSHS, and compare housing prices in the corresponding areas. We find that the designation did increase housing prices, showing that market information regarding the quality of schools is imperfect. We also find that the provision of other public goods, like green space and metro stations, are capitalized into housing prices. The effect on housing prices by increasing one best EMSHS per square kilometer in one residential area is the equivalent to that of increasing green space by 5.4 hectares, of reducing the distance to the metropolitan center by 4.6 kilometers, or of moving 6.0 kilometers nearer to the sub-centers.

The remainder of the paper is organized as follows: Section 2 reviews the literature. Section 3 introduces the background of compulsory education reform and housing market development in Shanghai. Section 4 reports data and econometric specifications. Section 5 reports empirical results. Section 6 reports several robustness checks. The last section concludes.

2. Literature Review

The relationship between local provision of public goods and housing prices is a classical issue in public and urban economics. Tiebout (1956) argued that if households are mobile and choose the community that provides local public goods for which they are willing to pay, then the local government will provide these local public goods more efficiently. Following studies showed that if the theory of Tiebout choice holds, the quality and quantity of local public goods, such as education, will be capitalized into housing prices (Oates, 1969; Yinger, 1982). In the general equilibrium analysis of local public goods and residential choice, the variance of preferences will lead to sorting in housing and consumption of public goods. When incorporating peer effects into education, parents have greater willingness to pay for better neighborhoods and better schools, thus sorting will be enhanced (Epple and Romano, 1998; Epple and Sieg, 1999; Rothstein, 2006).

Since Oates (1969) empirically analyzed the effects of property taxes and local public spending on property values, there have been numerous empirical studies on the correlation between the provision of public goods and housing prices in the United States and Europe. A hedonic price model has been commonly used in the econometric specifications of housing price studies, which includes both individual characteristics and location characteristics of houses as explanatory variables (Rosen, 1974; Anderson, 1985; Epple, 1987). Empirical results have been ambiguous, but it has been generally observed that differences in public goods, such as education, among local administrative districts are capitalized into housing prices. This result implies that Tiebout choice definitely exists in developed housing markets (Rubinfield, 1987; Rubinfield, Shapiro and Roberts, 1987; Epple and Sieg, 1999).

However, the endogeneity problems of missing variable bias and two-way causality may exist in early empirical studies on the education–housing price relationship. Unobservable neighborhood attributes and housing characteristics may affect both local education and housing prices. Besides, availability of quality schools may be a function of housing prices because people who can afford more expensive homes are more likely to afford good

education for their children. To control these potential endogeneity biases, Black (1999) used data of houses near the borders of neighboring school districts in Massachusetts to compare housing prices and school quality on different sides of the shared border. The core explanatory variable was the school's average test score in a statewide assessment, the Massachusetts Educational Assessment Program. Estimated via a hedonic price model, Black's conclusion was that a 5% increase in elementary school test scores leads to an increase in the marginal resident's willingness to pay of approximately 2.1%. Black's use of the BDD method was followed by Gibbons and Machin (2003), Bayer and McMillan (2005), Kane, Staiger, and Reigg (2005), and Gibbons, Machin, and Silva (2009).

In this study, we adopt a different method to deal with the endogeneity problem. We use panel data of 52 residential areas in Shanghai, the commercial center of mainland China, spanning 48 months, and utilize a natural experiment. During the education reform in Shanghai, 50 quality schools were designated as Shanghai Experimental Model Senior High Schools (EMSHS). The designation was related only to school quality, thus it offered a natural experiment for investigating whether information about quality schools affects housing prices. Our approach parallels that of Figlio and Lucas (2004), who compared housing prices before and after the State of Florida began to assign grades to schools based on test scores. They found that housing prices increased in areas with higher-graded schools compared to areas with lower-graded schools, but the estimated effect diminished over time. In our investigation, however, the effect on housing prices persists after a school is designated for EMSHS . This implies that information about school quality and its accessibility influences prices in a developing housing market.

There are a few empirical studies on the correlation between provision of public goods and housing prices in China, but how local education quantity and quality is capitalized into housing prices is not well estimated. For example, Wang et al. (2007) found that access to subway stations, bus stops, and parks is capitalized into housing prices, but not into land prices in Beijing. Zheng and Kahn (2008) used Beijing housing data and found that houses closer to high-quality schools had higher prices. However, this study also suffered from

endogeneity. Compared to the existing literature, the natural experiment in this study is more efficient in controlling endogeneity when estimating how the quality and quantity of schools influence housing prices and how that influence changes over time.

3. Compulsory Education and Housing Markets in Shanghai

Education reform and housing market development in Shanghai, mainland China's most populous city and its largest commercial center, comprise a representative case for China. Since the 1990s, compulsory education and the housing market in Shanghai have changed significantly because of China's reform toward a market economy. In 1997, entrance examinations for junior high school were replaced by the policy of "attending nearby schools." This practice is similar to the neighborhood-based school admissions system in the United States and some European countries, and it strengthens the relationship between the housing market and access to quality education. However, private schools also developed rapidly during the early years of China's education and market reforms. Some primary and high schools, usually the better ones, were partially privatized.[1] Several years later, following criticism that education reform had created unequal access to education, most partially privatized schools were retransformed to public schools. However, the change of ownership structure did not greatly affect schools' quality and reputation.

Following reforms that transformed public housing to a private system, Shanghai's housing market has grown rapidly in recent years. Today housing provisions are less frequently included in employee welfare, and therefore an increasing numbers of people buy and sell housing in market transactions. The former public housing has been privatized and can also be traded in the market. Sato (2006) provided empirical evidence for housing inequality in urban China after the reforms in the late 1990s. Development of a housing market enables people in effect to choose schools by purchasing an apartment. The rapid increase in housing

[1] These schools are called *Minban Zhuanzhi Xuexiao* ("schools with transformed ownership and run by people"). Similarly, private schools are usually called *Minban Xuexiao* ("schools run by people").

prices since 2003 has provided an opportunity to study the capitalization of education geographically and chronologically.

3.1 The "Attending Nearby Schools" System

The traditional compulsory education system in China was elitist. There were "core" primary schools, junior high schools, and senior high schools at different geographical levels. Those core schools commanded the best education resources and admitted students on the basis of entrance examinations. Enrollment under the "attending nearby schools" system is based on parents' *hukou* ("household registration"). If parents have not been granted *hukou* where they reside, their children cannot attend nearby quality public schools, but can only attend mediocre public schools or private schools. In the early stages of "attending nearby schools" reform, private schools and partially privatized schools were allowed to enroll students from other districts, and they selected and charged students in several different ways. Former core high schools offered "special classes," "artist classes," or "experimental classes" to attract students who performed well in examinations.[2]

After 2003 and the reconsideration of an education system structured as a market, school choice has been viewed as hindering equality of educational opportunity. The "attending nearby schools" system has been continuously strengthened to promote educational equity. Since 2005, academic competitions at the primary school level, an important tool for selecting students based on ability, have been forbidden in every province. Primary schools and junior high schools have been disallowed from vying for excellent students. In 2006, the Shanghai Municipal Commission on Education (SMCE) disallowed public schools from enrolling students on the basis of tests and prohibited private schools from meeting students prior to enrollment. In 2007, the Shanghai government further regulated private schools' attempt to enroll students across districts. The policy was interpreted as meaning that private schools also would implement the "attending nearby schools" policy. However, although the system of "attending nearby schools" has been strengthened, school choice through housing

[2] Some of the best Shanghai schools hold one-third of their enrollment open for specially selected students.

market can not be controlled. In effect, the “attending nearby schools” system means parents can choose a school by choosing their residence. Thus, the system has strengthened the relationship between housing prices, educational access, and school quality.

3.2 The History of Shanghai Core High Schools

Shanghai Core High Schools have a long history. The first were designated in the 1950s, and by 2002 there were 33 Shanghai Core High Schools. Under the traditional education system in China, these schools enjoyed the best educational resources and enrolled the best students through uniform entrance examinations. Whether because of teaching quality, school facilities, or peer effects among students, the superiority of core high schools was evident in their students’ college entrance examinations. Under education reform in the 1990s, the term “core junior high schools” was abandoned in pursuit of equal education, but the difference in quality among schools never disappeared. The junior sections of core high schools still have large advantages over other schools.

Although enrollment in senior high schools in Shanghai is decided by a city-level uniform examination (unlike the “attending nearby school” system for junior high school enrollment), before 2005 students were allowed to make only one of the total 16 applications for one of the 12 core high schools. Their remaining 15 applications were restricted to schools in their own district. Some students moved to other districts before the examination because their home location was important when applying for core high schools at that time.

In recent years, SMCE replaced the term “Shanghai Core High Schools” with “Shanghai Experimental Model Senior High Schools” (EMSHS). However, during the period of our data set (April 2003 to April 2007), the 33 traditional Shanghai Core High Schools still represented the top level of Shanghai senior high school education. Also in 2005, Shanghai reformed the enrollment practices of senior high schools. Today, at least 15% of the enrollment of every Shanghai Core High School must be open to students from other districts. Today a student can choose one of 50 EMSHS (including the traditional Shanghai

Core High Schools) among his 16 applications. Thus, home location has become a lesser factor in senior high school enrollment. However, the enrollment quota for schools in each district is still established before examinations, and districts containing a core school have more quotas to access that school than other districts. Therefore, parents still have an incentive to improve their children's chances to attend a core high school by purchasing an apartment within that school's district.

3.3 The Designation of Shanghai Experimental Model Senior High Schools (EMSHS)

In February 2005, September 2005, and July 2007, SMCE designated 50 schools for EMSHS designation in three waves. According to SMCE, "the senior high schools and senior sections of high schools within Shanghai, after being admitted by the government of their own district, can all participate in the public appraisal of EMSHS."[3] So, after several rounds of appraisals and designations, the government gave the market a clear indication of which schools were high-quality schools. Although there is no evidence that the designation itself improves school quality, it initiates the natural experiment to identify whether information about school quality influences housing prices.

4. Data and Econometric Specification

This study's empirical analysis answers two questions. First, within Shanghai Municipality, do differences in quantity and quality of education influence housing prices? Second, is the influence of education on housing prices changing with the education policies and the development of the housing market?

Prices for existing homes were chosen as samples because China's market in newly constructed housing tends to be more speculative. Thus, data concerning existing homes more accurately suggests residential demand for housing. Further, since only housing owners may send children to nearby quality public schools, we excluded housing rental data. As we

[3] "The Ideas of Shanghai Municipal Commission of Education for the Appraisal of Experimental Model Senior High Schools," a document of SMCE.

also noted, people cannot receive *hukou* by renting an apartment. For these and other reasons, apartment rents may not fully capitalize education quality.[4] Thus, we focus on housing prices instead of housing rents in this empirical study. This may partly explain why housing rents are low compared with housing prices in China. Of course, the lack of similar data for new housing and rent is another reason to use only existing home prices.

In addition, we match schools that were included in the first wave of EMSHS designations with schools of similar quality but not designated for EMSHS standing in first wave, and we compare housing prices of the corresponding areas. If the result is that designation itself significantly affects housing prices, it will also provide evidence that information about school quality is imperfect in education market.

4.1 Data

The dependent variable is constructed using the data for prices of existing housing. The key explanatory variable is the quantity of Shanghai Core High Schools, and Shanghai Experimental Model Senior High Schools. Other attributes, including the number of metro stations, top level hospitals, and the area devoted to public green space, are matched with the data for housing prices and education. Details of data construction are as follows.

Housing Prices

From publications of the Shanghai Secondhand Housing Price Index Office, we obtained monthly data of average prices per square meter for existing houses in 52 residential areas within Shanghai from April 2003 to April 2007[5]. Those 52 residential areas are larger than school districts but smaller than administrative districts. They are located in 11 administrative districts downtown and in suburbs of Shanghai. Each administrative district encompasses three to seven residential areas. The scope of a residential area consists of several school districts. The boundary difference between one residential area and the extent

[4] But we cannot deny that the quality of schools may be indirectly capitalized into housing rents.
[5] After April 2007, the office released only a monthly city-level aggregate index instead of specific prices.

of school districts in the residential area is minor, because well-known avenues and structures are used to define boundaries of residential areas.

Data used in this study span April 2003 through April 2007, mainly because of availability. It is a coincidence that 2003 was the beginning of enhancing “attending nearby schools” policy and also marked the onset of rapid growth of housing prices.

Education

As suggested in the introductory discussion on education in Shanghai, we used the number of Shanghai Core High Schools per square kilometer (denoted as “Core”) to measure the quality and quantity of education within each residential area. To analyze whether the designation for Shanghai Experimental Model Senior High Schools influenced housing prices, the education data also include the number of Shanghai Experimental Model Senior High Schools per square kilometer (denoted as “EMSHS”). The main sources of data on school distribution are the official website of SMCE and other education websites in Shanghai (http://www.shmec.gov.cn; http://www.edu.sh.cn; http://www.shmeea.com.cn). We use Shanghai’s map to match data concerning housing prices and education.

Figure 1 illustrates the relationship between housing prices and the number of quality schools. The slope of fitted lines is always positive, which shows possible positive correlations between housing prices and the number of quality schools within the residential area.

< Figure 1 about here.>

Other Public Goods

Provision of other public goods might influence housing prices. To measure their possible influence, we include hectares of public green space per square kilometer (denoted as “Green”), the number of metro stations per square kilometer (denoted as “Metro”), and the

number of top-level hospitals per square kilometer (denoted as “Hospital”) within each residential area. Data regarding public green space was sourced from the Shanghai Green and Urban Amenities website (http://lhsr.sh.gov.cn) and from government websites of related districts in Shanghai. Data regarding metro stations and hospitals were taken from the Shanghai Traffic Map (Shanghai Surveying and Mapping Institute and Chinese Map Publishing House, 2004, 2009) and related websites of the Shanghai Municipal Government.

Distance

Location is an important exogenous factor determining housing prices. Our econometric analysis controls two location variables: “Dcenter”—the straight line distance to the People’s Square in the metropolitan center of Shanghai—and “Dsub-center”—the straight line distance to the nearest sub-centers. Before the end of 2007, there were three sub-centers in the city-planning of Shanghai: Xujiahui, Wujiaochang, and Pudong Huamu.

<Table 1 about here.>

4.2 Econometric Specification

4.2.1 Panel Data Econometric Model

Our econometric model to analyze the relationship between housing prices and access to quality education is derived from the hedonic housing price model used by Black (1999) and Wang et al. (2007). Because the data we use are values per square kilometer of each residential area, explanatory variables also pertain to the area level. A linear monthly time trend is controlled to capture the stable growth of housing prices. Because China’s housing market is growing rapidly, the capitalization of education should be considered as a dynamic process. Therefore, we control the interaction terms of education and time to examine the influence of education on price changes over time. By the same token, the interaction terms of other public goods and time are also controlled for. Thus, we get Equation (1) as follows:

$$\ln(housingprice_{it}) = \beta_0 + \beta_1 \cdot distance_i + \beta_2 \cdot education_{it} + \beta_3 \cdot education_{it} \cdot time + \beta_4 \cdot public_{it} + \beta_5 \cdot public_{it} \cdot time + \beta_6 \cdot time + \beta_7 \cdot control_{it} + \alpha_i + \varepsilon_{it}$$

——（1）

The subscript i in Equation (1) denotes the residential area, and t denotes month within the time span April 2003 to April 2007. $housingprice_{it}$ denotes housing prices per square meter of area i in month t. We use the natural logarithm of housing prices as the dependent variable. $distance_i$ represents a vector of the distance to the metropolitan center (Dcenter) and the distance to the nearest sub-centers (Dsub-center). $education_{it}$ denotes the number of high-quality schools in area i, which is the key explanatory variable in the analysis. $public_{it}$ is the provision of other public goods, including green space, metro stations, and hospitals. $time$ denotes the monthly time trend variable. The initial month, April 2003, is denoted as 1, and increased by 1 at one-month intervals. Since there was a definite change in the rate of increase in housing prices around May 2005 (as shown in Figure 2), we divide the variable $time$ into two parts:

$$time1 = (1 - D200505) \times time \quad (2)$$

$$time2 = D200505 \times time \quad (3)$$

D200505 is a dummy variable, denoted as 1 for periods after May 2005, and otherwise denoted as 0. The interaction terms between this time variable and other variables are mostly significant in the results reported, indicating that the turning point of housing prices is statistically significant.

< Figure 2 about here.>

The interaction terms between time and education and other public goods are controlled in the model.[6] $control_{it}$ includes other control variables. In particular, we add the interaction

[6] If we control time squares and the interaction terms between that and other explanatory variables, almost all the coefficients of these terms are insignificant. The significance of other variables' coefficients

terms of metro and distance variables to the model. We assume that in areas far from the metropolitan center and sub-centers, the effects of metro stations of improving traffic convenience dominate, which is positive for housing prices; however, in areas near the metropolitan center or sub-centers, the convenience of nearby metro stations is not important, yet congestion effects might dominate when metro stations concentrate in a small area. To model the nonlinear effect of metro stations, we control the interaction terms between Metro and Dcenter and between Metro and Dsub-center in the model. α_i denotes unobservable residential area attributes, including geographic characteristics, the city-planning of streets and buildings, and similar attributes. ε_{it} denotes the random error term.

To control the influence of unobservable factors, we use the following two models based on different assumptions. The first is a fixed-effects (FE) model. After within-group de-mean transformation, the fixed effect, α_i, is eliminated. We then performed OLS estimation. The second model is a random effects (RE) model. We assume α_i is not correlated to explanatory variables, then estimate the model by generalized least squares. The Hausman test is used to discriminate the two alternative assumptions.

4.2.2 The Designation of Shanghai Experimental Model Senior High Schools

The designation of a school as a Shanghai Experimental Model Senior High School is related to its quality and is not influenced by housing prices. Therefore, a reverse causal effect from housing prices to school quality can be eliminated. To analyze whether the designation influenced housing prices, we substitute Core and its interaction term with EMSHS and its interaction term with time on the base of Equation (1). Because those high-quality schools had existed before being designated as EMSHS, the term “EMSHS” in the regression denotes only the number of schools designated for EMSHS standing. The time of designation and the number of schools designated in each wave are denoted by terms “Designation1” (the number of first-wave EMSHS per square kilometer) and “Designation2”

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are also influenced.

(the number of second-wave EMSHS per square kilometer).[7]

Further, we match the schools designated for first-wave EMSHS standing with the schools of similar quality that were not designated, and we compare housing prices in the corresponding areas. By this method, we get Equation (4) as follows:

$$\ln(housingprice_{it}) = \gamma_0 + \gamma_1 \cdot distance_i + \gamma_2 \cdot EMSHS1L_i + \gamma_3 \cdot D200502 + \gamma_4 \cdot EMSHS1L_i \cdot D200502 + \gamma_5 \cdot time + \gamma_6 \cdot control_{it} + \varepsilon_{it}$$

——（4）

The estimation of Equation (4) is based on sub-samples of four residential areas. Two had former core high schools that were not included in the first wave of EMSHS designations in February 2005. The other 2 residential areas had schools with similar quality but were designated in the first wave. There has been no official disclosure of school quality rankings in Shanghai. However, informal quality rankings for guiding school choice in Shanghai are available on the Internet. We are unable to confirm whether each informal ranking is exact, but we find that two of the first-wave EMSHS are always ranked lower in different rankings. We then match those two schools with the former core high schools that were not included in the first wave of EMSHS designations. The variable “EMSHS1L” denotes the number of schools with similar quality but designated as first-wave EMSHS per square kilometer in each residential area. “D200502” is a dummy variable valued at 1 for periods after February 2005 and 0 otherwise. The coefficient of the interaction term between EMSHS1L and D200502 is the estimation of the effect on housing prices of schools in a residential area being included in the first wave of EMSHS designations.

[7] The third wave of designations occurred outside our data period and is not considered in the analysis.

5. Empirical Results

Table 2 reports the results of Equation (1) for the panel data of 52 residential areas. Column (1) shows the result of FE estimation, and Column (2) shows the result of RE estimation. The Hausman test statistic is 48.59, with p value 0.000. Because the null hypothesis of the Hauman test is that there are no systematic differences between FE and RE results, the test result implies that FE estimation should be the final result. In fact, the difference between the results in Columns (1) and (2) is only that of the magnitude of the coefficients, but the sign and significance are mostly consistent.

<Table 2 about here.>

The results presented in Table 2 show that Core is significantly positive, and its interaction term with both time1 and time2 are negative but not significant. When an area has one additional quality school per square kilometer, housing prices will be approximately 19.2% higher. By comparing explanatory variables, we observe that the effect on housing prices by increasing one Shanghai Core High School per square kilometer in one residential area is equivalent to that of enlarging green space by 4.2 hectares, of moving 5.1 kilometers nearer to the metropolitan center, or of moving 6.7 kilometers nearer to the sub-centers. Most Shanghai Core High Schools have existed for several decades or longer. Their influence was long ago incorporated into housing prices.

Table 2 demonstrates that the provision of other public goods also is capitalized into housing prices. The coefficient of Green is significantly positive. Housing prices are approximately 4.54% higher in areas that have one more hectare of green space per square kilometer. The coefficient of Metro is significantly negative, and its interaction term with Dcenter is not significant, while its interaction term with Dsub-center is significantly positive. At about 7.4 kilometers from the sub-centers, the effects of metro stations on housing prices turn from negative to positive. The result is consistent with the finding in Gu and Zheng (2009) about the influence of Beijing's No. 13 metro line on nearby housing prices. They find that in

suburban areas housing prices within 1 kilometer of railway stations are nearly 20% higher than those beyond that distance, but the effect is not significant in downtown areas. The possible explanation is that transportation is already convenient in central metropolitan areas, where the influence of metro stations is mainly negative on housing prices because of congestion. But at some distance from the metropolitan center or sub-centers, traffic convenience becomes the major contribution of metro stations, which is positive on housing prices. Further, in a multi-center city like Shanghai the positive effects mainly depend on the distance to sub-centers.

The coefficient of “Hospital” and its interaction term with time are not significant, possibly because access to hospitals has two different effects simultaneously: getting to a hospital is more convenient (positive effect on housing prices) but environmental effects are negative (negative effect on housing prices). On average, those effects negate each other.

Moreover, the coefficients of Dcenter and Dsub-center are significantly negative. Considering Shanghai’s spatial economic structure wherein economic activities concentrated in the center and sub-centers of the city, the result that housing prices (land rents) are determined by job location and traffic cost is consistent with the theoretical models of Alonso (1964) and Zenou (2008). It is also consistent with Hao and Chen’s (2007) empirical findings of how location influences housing prices for 106 blocks within Shanghai.

Table 3 reports the influence of EMSHS designation on housing prices. Column (3) in the table is the FE result, and Column (4) is the RE result. The Hausman test is 40.28 with p value 0.0007, rejecting the null hypothesis of no significant difference between the FE and RE results. Thus, our discussion is based on FE results.

<Table 3 about here.>

First, the coefficient of EMSHS is significantly positive, and its interaction terms with time1 and time2 are significantly negative. These results imply that EMSHS as high-quality schools decidedly influence housing prices, and the influence was already present earlier.

The negative interaction terms are probably due to the 2005 enrollment reform that relaxed EMSHS restrictions on enrolling students from other districts. Second, the coefficients of Designation1 and Designation2 are significantly positive, and the value of first coefficient is 2.4 times greater than that of the second. In the last period within the data set (April 2007), when a residential area has one more first-wave EMSHS per square kilometer, housing prices are approximately 21.7% higher. This increase is equivalent to the effect of increasing green space by 5.4 hectares, of moving 4.6 kilometers toward the metropolitan center, or of moving 6.0 kilometers nearer to the sub-centers. The results imply that the designation of EMSHS discloses information about school quality, and it definitely influences housing prices.

Further, because the different waves of designation resulted from competition among many schools, schools included in the first wave of EMSHS designations were well-known schools. All 28 schools designated in the first wave had been Shanghai Core High Schools, while only three of 11 schools in the second wave had been core schools. The information from the first wave of designations had been capitalized into housing prices. In comparing the effects of Core on housing prices in Table 2, we observe that the first wave of EMSHS designations had a greater influence on housing prices. This is understandable, because the estimation in Table 2 is an average effect of core schools, while the first-wave designated EMSHS were the best among core schools. Moreover, the sign and significance of other variables in Table 3 are consistent with those in Table 2.

Finally, Table 4 shows the results of estimation on first wave EMSHS designation. The coefficient of EMSHS1L is not significant, which implies that the effects of those sample schools on housing prices were nearly the same at the beginning. This interpretation is reasonable because we matched schools of similar quality according to informal school quality rankings. The interaction term between EMSHS1L and D200502 is significantly positive, implying that the information of EMSHS designation has been capitalized into housing prices. The value is 0.0612, a much lower estimate compared with the effect of designation in the previous estimation. This is understandable, as we did not control for

quality variances among schools designated in the first-wave, whereas this calculation compares the effects of designated and non-designated schools of similar quality. However, we still base our evaluation of the effect of school quality on housing prices on the previous estimation in Table 3, because the real effect of designation should be expressed as the average effect of designating schools of different qualities.

<Table 4 about here.>

6. Robustness Check

Table 5 reports the results of several robustness checks performed on the estimation. First, Pudong District is separated by the Huangpu River from the metropolitan center; therefore, a straight-line measurement of distance to the center underestimates the real distance. Pudong began its speedy development in the early 1990s, and the history of its educational development might not be comparable to other districts. Therefore, we performed a robustness check in Columns (6) and (7) using sub-samples without Pudong, and observed that the signs and significance of variables are almost the same as Table 2. We performed another robustness check by considering the sub-samples of residential areas near the metropolitan center alone. By estimating the sub-samples of 34 residential areas within eight kilometers of the metropolitan center in Columns (8) and (9), we found no change in signs and significance of main variables. Finally, Columns (10) and (11) show the results of estimation without interaction terms to test whether our results for education–housing price relationship are robust under different functional forms. The effects of Shanghai Core High Schools and of the designation in the first wave of EMSHS remain significant.

<Table 5 about here.>

7. Conclusions

Endogeneity of education quality and quantity causes difficulties in identifying the causal

relationship between education and housing prices. To determine how significantly education quality has been capitalized into housing prices, we utilized a natural experiment occasioned during China's education reform to deal with the endogeneity bias. On the basis of the exogenous natural experiment of EMSHS designation, we observed that housing prices in Shanghai have capitalized the quality and quantity of education along with other public goods. One quality school per square kilometer raises housing prices by approximately 19%, and one best EMESHS per square kilometer increases housing prices by 21%. The effect on housing prices by increasing one best EMSHS per square kilometer in one residential area is the equivalent to that of increasing green space by 5.4 hectares, of reducing the distance to the metropolitan center by 4.6 kilometers, or of moving 6.0 kilometers nearer to the sub-centers. The capitalization changes over time when schools are allowed to or restricted from enrolling students from other districts. Restricting enrollment across districts enhances the relationship between school quality and housing prices, while deregulation weakens the relationship. The capitalization of other public goods such as public green space and metro stations also appears in the Shanghai data. The positive effects of metro station are found only in locations more than seven or eight kilometers distant from the sub-centers. Because the exogenous natural experiment has efficiently eliminated the influence of endogeneity, our finding that educational quality is capitalized in housing prices is a convincing empirical evidence. Also, the finding that EMSHS designation itself has significant effects on housing prices provides evidence that information regarding school quality is imperfect in Shanghai's developing education and housing market.

Our empirical findings present important evidence of Tiebout choice occurring in China's metropolitan housing market, which is a key mechanism in making education policy. When education resources are allocated through the housing market, the regulations for seemingly equalized educational access, for instance, regulating school choice and school choice fees, may enhance the education–housing price relationship, making people compete for educational resources through housing choices and widening the inequality of educational access.

References

Alonso, W., 1964, *Location and Land Use*, Cambridge, MA: Harvard University Press.

Anderson, J. E., 1985, "On Testing the Convexity of Hedonic Price Functions," *Journal of Urban Economics*, Vol. 18, No. 3, Nov., pp. 334-337.

Bayer, P., and R. McMillan, 2005, "Choice and Competition in Local Education Markets," NBER Working paper 11802.

Black, S. E., 1999, "Do Better Schools Matter? Parental Valuation of Elementary Education," *Quarterly Journal of Economics*, Vol. 114, No. 2, May, pp. 577-599.

Epple, D., 1987, "Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions for Differentiated Products," *Journal of Political Economy*, Vol. 95, No. 1, Feb., pp. 59-80.

Epple, D., and R. E. Romano, 1998, "Competition between Private and Public Schools, Vouchers, and Peer-Group Effects," *American Economic Review*, Vol. 88, No. 1, Mar., pp. 33-62.

Epple, D., and H. Sieg, 1999, "Estimating Equilibrium Models of Local Jurisdictions," *Journal of Political Economy*, Vol. 107, No. 4, Aug., pp. 645-681.

Figlio, D., and M. Lucas, 2004, "What's in a Grade? School Report Cards and the Housing Market," *American Economic Review*, Vol. 94, No. 3, Jun., pp. 591-604.

Gibbons, S., and S. Machin, 2003, "Valuing English Primary Schools," *Journal of Urban Economics*, Vol. 53, No. 2, Mar., pp. 197-219.

Gibbons, S., S. Machin, and O. Silva, 2009, "Valuing School Quality Using Boundary Discontinuities," SERC Discussion Papers.

Gu, Y., and S. Zheng, 2009, "The Impacts of Rail Transit on Property Values and Land Development Intensity: The Case of No.13 Line of Beijing," (in Chinese), Working paper, Institute of Real Estate Studies, Tsinghua University.

Hao, Qianjin, and Jie Chen, 2007, "Distance to CBD, Transportation Accessibility and the Spatial Differences of Residential Housing Prices in Shanghai," (in Chinese), *World Economic Papers* (*Shijie Jingji Wenhui*), No. 1, pp. 22-35.

Kane, T., D. O. Staiger, and S. K. Reigg, 2005, "School Quality, Neighborhoods and Housing Prices: The Impacts of Desegregation," NBER Working Paper 11347.

Oates, W. E., 1969, "The Effects of Property Taxes and Local Public Spending on Property Values: An Empirical Study of Tax Capitalization and the Tiebout Hypothesis," *Journal of Political Economy*, Vol. 77, No. 6, Nov. - Dec., pp. 957-971.

Rosen, S., 1974, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy*, Vol. 82, No. 1, Jan. - Feb., pp. 34-55.

Rothstein, J. M., 2006, “Good Principals or Good Peers? Parental Valuation of School Characteristics, Tiebout Equilibrium, and the Incentive Effects of Competition among Jurisdictions,” *American Economic Review*, Vol. 96, No. 4, Sep., pp. 1333-1350.

Rubinfield, D. L., 1987, “The Economics of the Local Public Sector,” In *Handbook of Public Economics*, Vol. 2, edited by Alan J. Auerbach and Martin Feldstein, Amsterdam: North-Holland.

Rubinfield, D. L., P. Shapiro, and J. Roberts, 1987, “Tiebout Bias and the Demand for Local Public Schooling,” *Review of Economics and Statistics*, Vol. 69, No. 3, Aug., pp. 426-437.

Sato, H., 2006, “Housing Inequality and Housing Poverty in Urban China in the Late 1990s,” *China Economic Review*, Vol. 17, No. 1, pp. 37-80.

Tiebout, C. M., 1956, “A Pure Theory of Local Expenditures,” *Journal of Political Economy*, Vol. 64, No. 5, Oct., pp. 416-424.

Wang, Yijun, Siqi Zheng, and Fenjie Long, 2007, “Who Benefit from and Who Pay for the Local Public Services in Chinese Cities: Some Policy Implications,” (in Chinese), *Urban Studies* (*Chengshi Fazhan Yanjiu*), No. 4, pp. 46-53.

Yinger, J., 1982, “Capitalization and the Theory of Local Public Finance,” *Journal of Political Economy*, Vol. 90, No. 5, Oct., pp. 917-943.

Zenou, Y., 2008, “Social Interactions and Labor Market Outcomes in Cities,” IFN Working Paper No. 755.

Zheng, S., and M. E. Kahn, 2008, “Land and Residential Property Markets in a Booming Economy: New Evidence from Beijing,” *Journal of Urban Economics*, Vol. 63, No. 2, Mar., pp. 743-757.

Table 1: Statistical Summary of Variables

Variable	Observations	Mean	Standard Deviation	Min.	Max.
Explained variable (unit: RMB/m^2)					
$housingprice_{it}$	2496	7993.11	1950.46	3514.00	13229.00
Explanatory variables					
(1) $education_{it}$ (unit: number/km^2)					
Core	2496	0.09	0.16	0.00	0.77
EMSHS	2496	0.15	0.26	0.00	1.54
(2) $public_{it}$ (unit: number/km^2)					
Green (hectares)	2496	2.45	3.36	0.00	15.90
Metro (number)	2496	0.21	0.27	0.00	0.89
Hospital (number)	2496	0.15	0.35	0.00	2.31
(3) $distance_i$ (unit: km)					
Dcenter	52	6.80	3.57	0.00	14.50
Dsub-center	52	4.99	2.29	0.00	12.00
Area (unit: km^2)	52	10.51	12.15	1.3	75

Table 2: Regression of Housing Prices on Explanatory Variables

Dependent variable: $\ln(housingprice_{it})$	(1) FE	(2) RE
Core	0.192**	0.164**
	(0.0829)	(0.0679)
Core × time1	–0.00359	–0.00320
	(0.00247)	(0.00249)
Core × time2	–0.00153	–0.00164
	(0.00111)	(0.00111)
Green	0.0454***	0.00880***
	(0.00904)	(0.00341)
Green × time1	–0.0000316	–0.0000335
	(0.0000891)	(0.0000899)
Green × time2	–0.0000696*	–0.0000633
	(0.0000389)	(0.0000392)
Metro	–0.483***	–0.152*
	(0.112)	(0.0893)
Metro × time1	–0.000740	–0.00118
	(0.00130)	(0.00130)
Metro × time2	0.0000928	–0.000387
	(0.000574)	(0.000571)
Metro × Dcenter	0.00196	–0.00418
	(0.0113)	(0.00962)
Metro × Dsub-center	0.0655***	0.0189
	(0.0146)	(0.0116)
Hospital		0.0224
		(0.0432)
Hospital × time1	0.00158	0.00142
	(0.00117)	(0.00118)
Hospital × time2	0.000752	0.000778
	(0.000510)	(0.000513)
time1	0.0170***	0.0173***
	(0.000437)	(0.000434)
time2	0.0135***	0.0137***
	(0.000199)	(0.000194)
Dcenter		–0.0321***
		(0.00389)
Dsub-center		–0.0244***
		(0.00592)

Constant	8.521***	8.923***
	(0.0235)	(0.0374)
Observations	2496	2496
R^2 (within groups)	0.829	0.827

Notes:

(1) Standard error in parentheses.

(2) *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 3: Influence of "Shanghai Experimental Model Senior High Schools" Designation on Housing Prices

Dependent variable: $\ln(housingprice_{it})$	(3) FE	(4) RE
EMSHS	0.207***	0.118**
	(0.0790)	(0.0546)
EMSHS × time1	–0.00552***	–0.00519***
	(0.00167)	(0.00168)
EMSHS × time2	–0.00690***	–0.00669***
	(0.00101)	(0.00101)
Designation1	0.348***	0.355***
	(0.0316)	(0.0316)
Designation2	0.145***	0.133***
	(0.0334)	(0.0334)
Green	0.0445***	0.00916***
	(0.00883)	(0.00342)
Green × time1	–0.0000581	–0.0000588
	(0.0000870)	(0.0000877)
Green × time2	–0.0000854**	–0.0000824**
	(0.0000380)	(0.0000382)
Metro	–0.331***	–0.0518
	(0.112)	(0.0900)
Metro × time1	–0.00127	–0.00164
	(0.00126)	(0.00127)
Metro × time2	–0.000170	–0.000597
	(0.000560)	(0.000556)
Metro × Dcenter	–0.00734	–0.0104
	(0.0111)	(0.00956)
Metro × Dsub-center	0.0488***	0.00723
	(0.0147)	(0.0117)
Hospital		0.00395
		(0.0488)
Hospital × time1	0.00173	0.00147
	(0.00129)	(0.00130)
Hospital × time2	0.000424	0.000292
	(0.000565)	(0.000567)
time1	0.0171***	0.0174***
	(0.000433)	(0.000431)
time2	0.0135***	0.0137***

	(0.000197)	(0.000193)
Dcenter		–0.0315***
		(0.00397)
Dsub-center		–0.0240***
		(0.00596)
Constant	8.505***	8.914***
	(0.0250)	(0.0382)
Observations	2496	2496
R^2 (within groups)	0.837	0.836

Notes:

(1) Standard error in parentheses.

(2) *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 4: Effects of First-wave "Shanghai Experimental Model Senior High Schools" Designation

Dependent variable: $\ln(housingprice_{it})$	(5) lnhp
EMSHS1L	–0.0774
	(0.0497)
D200502	0.206***
	(0.0200)
EMSHS1L × D200502	0.0612***
	(0.0183)
Green	0.0280
	(0.0259)
Metro	–0.130**
	(0.0501)
time1	0.0109***
	(0.000902)
time2	0.00556***
	(0.000650)
Distance1	–0.0167
	(0.0272)
Distance2	–0.0569***
	(0.00921)
Constant	9.075***
	(0.186)
Observations	192
R^2	0.946

Notes:

(1) Standard error in parentheses.

(2) *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 5: Robustness Checks

	(6)	(7)	(8)	(9)	(10)	(11)
Dependent variable:	FE	FE	FE	FE	FE	FE
$\ln(housingprice_{it})$						
Core	0.204**		0.139*		0.128*	
	(0.0852)		(0.0840)		(0.0741)	
Core × time1	–0.00323		–0.00343			
	(0.00256)		(0.00265)			
Core × time2	–0.00178		–0.00147			
	(0.00114)		(0.00120)			
EMSHS		0.223***		0.134*		0.159**
		(0.0810)		(0.0797)		(0.0734)
EMSHS × time1		–0.00540***		–0.00434**		
		(0.00173)		(0.00171)		
EMSHS × time2		–0.00699***		–0.00495***		
		(0.00104)		(0.00103)		
Designation1		0.338***		0.265***		0.180***
		(0.0325)		(0.0329)		(0.0208)
Designation2		0.149***		0.0865**		–0.0582***
		(0.0342)		(0.0337)		(0.0199)
Green	0.0429***	0.0417***	0.0383***	0.0402***	0.0446***	0.0466***
	(0.00939)	(0.00917)	(0.0104)	(0.0102)	(0.00881)	(0.00869)
Green × time1	–0.000108	–0.000154	–9.21e-05	–0.000135		
	(0.000111)	(0.000108)	(0.000120)	(0.000117)		
Green × time2	–6.04e-05	–9.01e-05*	–0.000141***	–0.000171***		
	(4.86e-05)	(4.74e-05)	(5.25e-05)	(5.14e-05)		
Metro	–0.414***	–0.266**	–0.906***	–0.887***	–0.122***	–0.118***
	(0.116)	(0.116)	(0.253)	(0.248)	(0.0228)	(0.0225)
Metro × time1	–0.00113	–0.00174	–0.000112	–0.000680		
	(0.00135)	(0.00132)	(0.00144)	(0.00142)		
Metro × time2	–0.000183	–0.000510	0.000354	1.17e-05		
	(0.000602)	(0.000589)	(0.000651)	(0.000645)		
Metro × Dcenter	–0.00634	–0.0166	0.0510*	0.0562**		
	(0.0119)	(0.0117)	(0.0275)	(0.0270)		
Metro × Dsub-center	0.0628***	0.0480***	0.101***	0.0968***		
	(0.0149)	(0.0150)	(0.0258)	(0.0254)		
Hospital × time1	0.00133	0.00159	0.00158	0.00155		
	(0.00121)	(0.00134)	(0.00120)	(0.00130)		
Hospital × time2	0.000626	0.000356	0.000648	0.000275		

	(0.000526)	(0.000587)	(0.000529)	(0.000576)		
time1	0.0175***	0.0177***	0.0169***	0.0171***	0.0167***	0.0164***
	(0.000499)	(0.000497)	(0.000562)	(0.000571)	(0.000304)	(0.000301)
time2	0.0138***	0.0139***	0.0137***	0.0138***	0.0133***	0.0129***
	(0.000230)	(0.000229)	(0.000261)	(0.000266)	(0.000139)	(0.000146)
Constant	8.541***	8.522***	8.659***	8.640***	8.511***	8.495***
	(0.0240)	(0.0259)	(0.0296)	(0.0326)	(0.0225)	(0.0239)
Observations	2160	2160	1632	1632	2496	2496
R^2	0.829	0.837	0.836	0.843	0.827	0.832

Notes:

(1) Standard error in parentheses.

(2) *** denotes significance at the 1% level, ** at the 5% level, and * at the 10% level.

(3) Columns (6) and (7) are based on sub-samples excluding Pudong. Columns (8) and (9) are based on sub-samples of 34 residential areas within 8 kilometers from the metropolitan center. Columns (10) and (11) are based on the samples of all 52 residential areas.

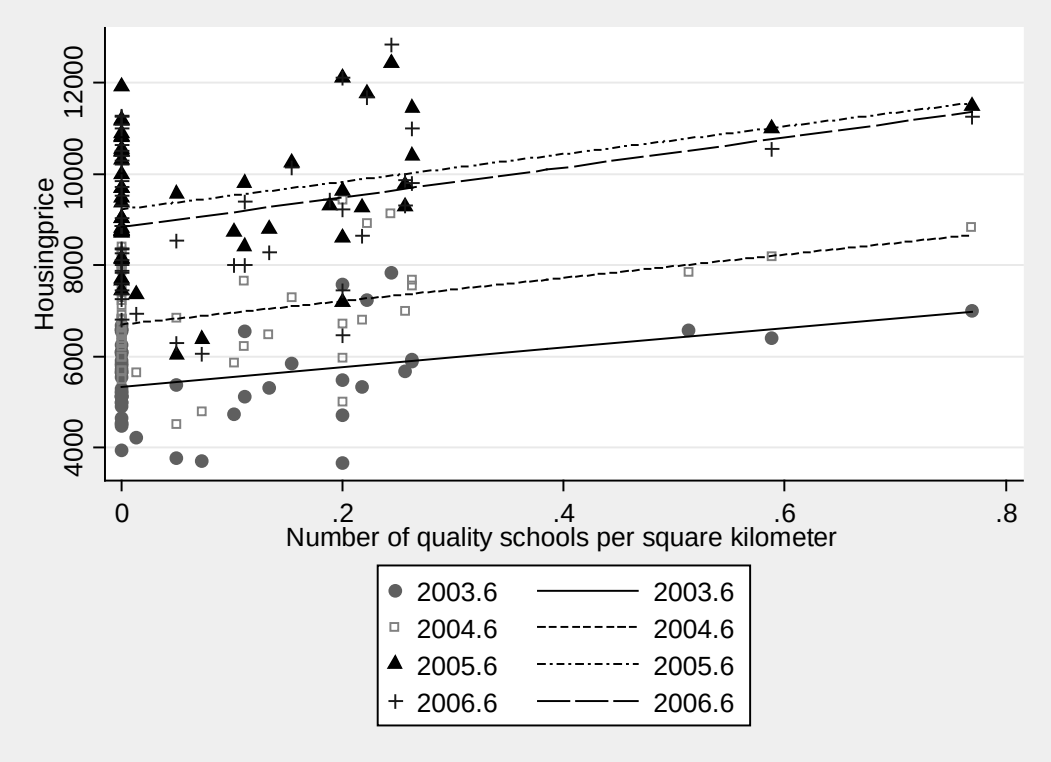

Figure 1: Correlation between Housing Prices and Quantity of Private and Partially-privatized Junior High Schools

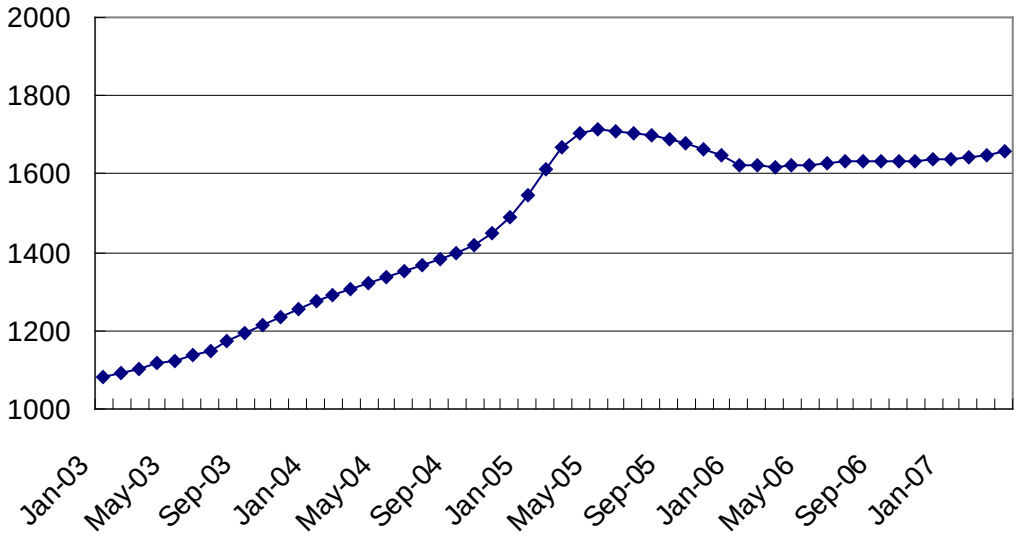

Figure 2: Price Index of Existing Home Sales in Shanghai